

Study of proton helicity structure in polarized $p+p$ collisions at RHIC

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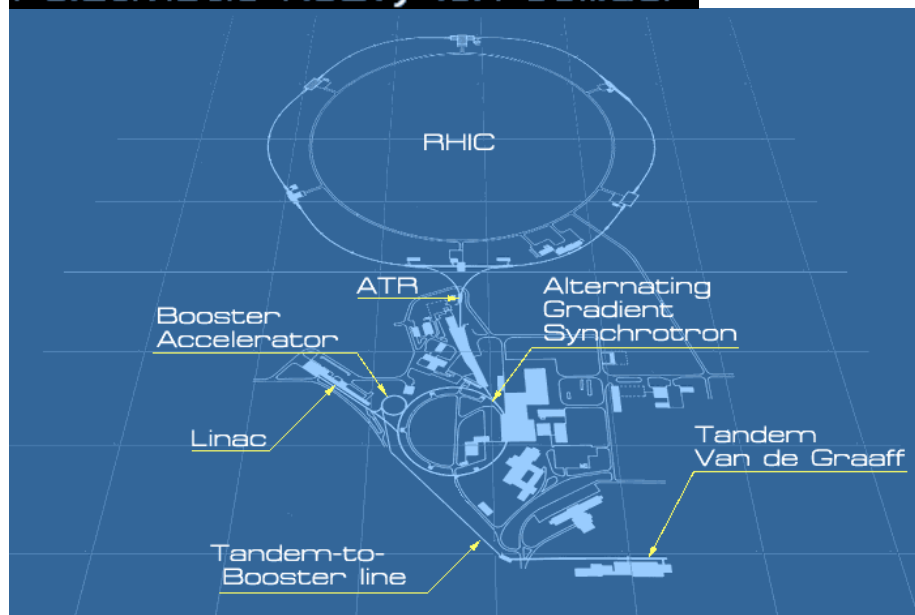
JPS September 22, 2007



Introduction

RHIC

relativistic heavy ion collider



The first polarized $p+p$ collider

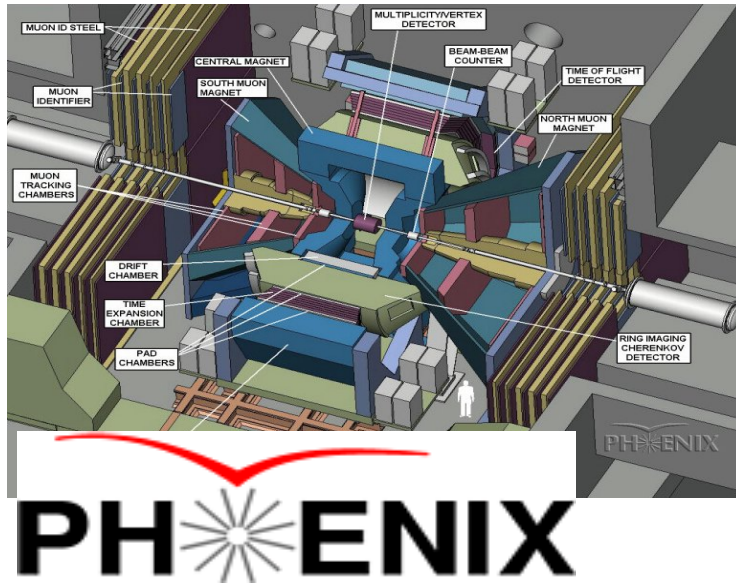
Polarized p : spin structure of proton

$p+p$: gluon in leading order process

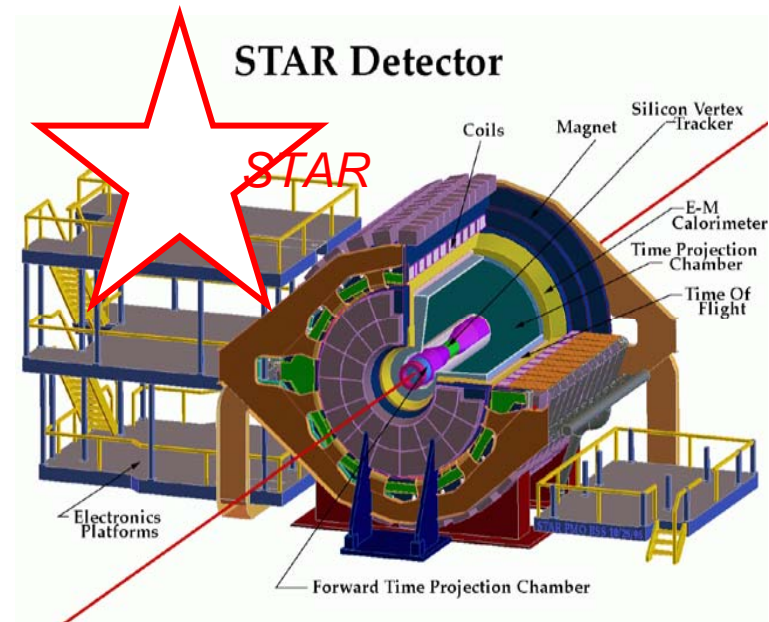
Collider : high \sqrt{s} , the perturbative QCD applicable.

This talk : experimental aspects of the proton helicity structure

Two large Detectors



PHENIX:
High rate capability
High granularity
Good mass resolution and PID
Limited acceptance



STAR:
Large acceptance with azimuthal symmetry
Good tracking and PID
Central and forward calorimetry

They plan to cover
their weak points
in upgrade programs.

Luminosity and Polarization

Year/Run	\sqrt{s} [GeV]	L_{average} [$10^{30} \text{ s}^{-1} \text{ cm}^{-2}$]	$\int L$ (STAR)	$\int L$ (PHENIX)	Polarization [%]
2002/Run2	200	1.5	-	-	15
2003/Run3	200	3	0.3	.35	35
2004/Run4	200	4	0.4	.12	46
2005/Run5	200	6	3.1	3.4	47
2006/Run6	200	20	8.5	7.5	60
2006/Run6	62.4	(no official number)	-	.08*	48*

The RHIC performance improves every year.
(Luminosity and polarization)

● Unpolarized Cross Section

- Unpolarized = spin averaged
- Before going to asymmetry measurements, we need to confirm the applicability of factorized pQCD.
 - pQCD calculation is used to extract Δg (for example sensitive x region)
 - Is the PDF measured by DIS experiments valid for $p+p$ collisions?
- Remarks

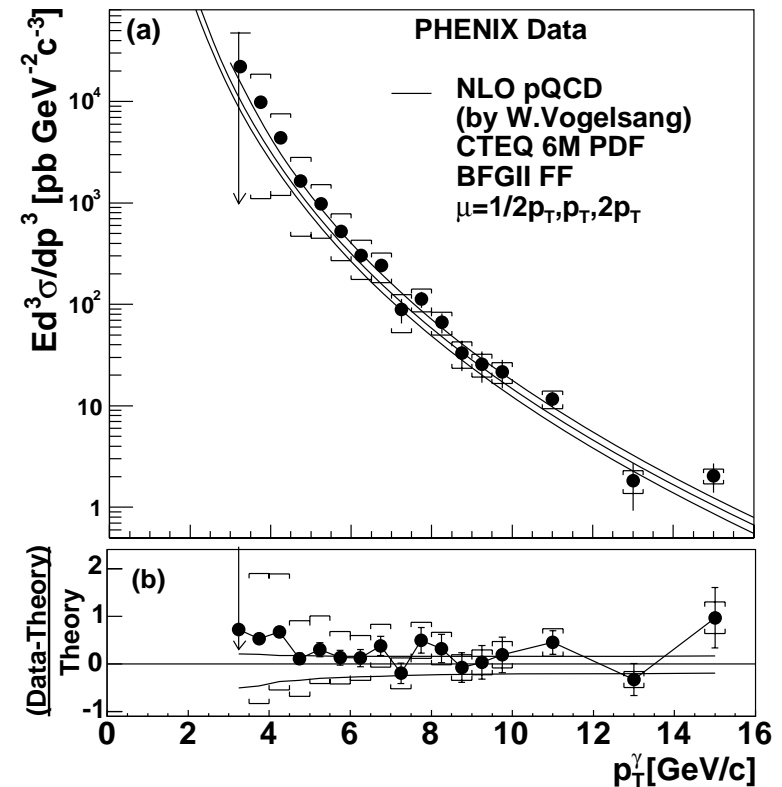
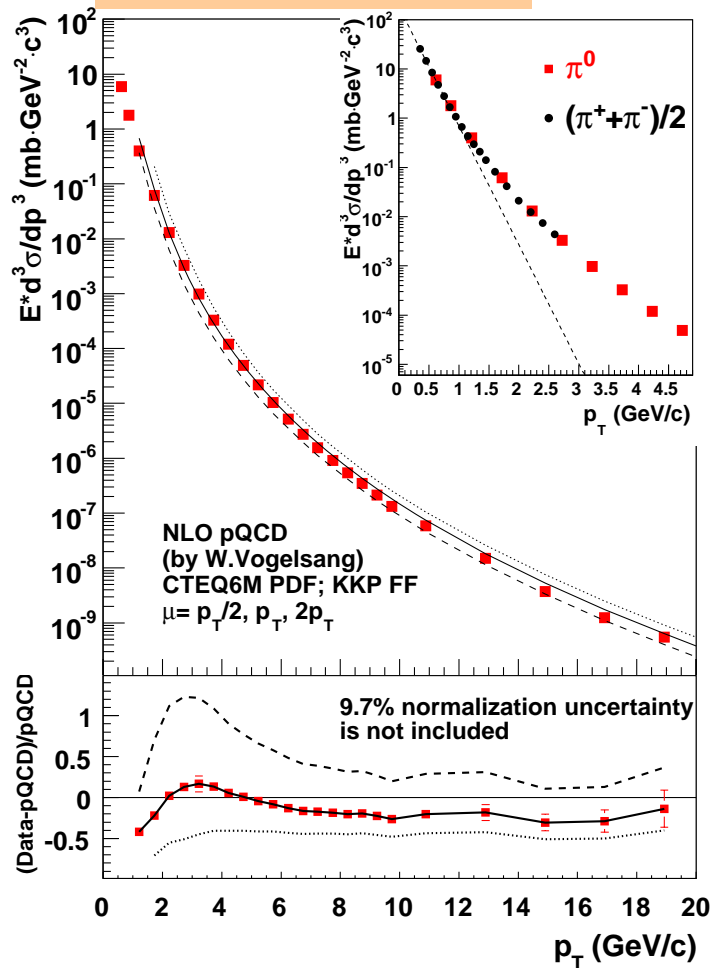
The calibration of energy scale is important for the steep falling spectra.
The normalization of total number of collisions is not trivial.

Measurements from PHENIX

$pp \rightarrow \pi^0 X$:
hep-ex-0704.3599

Sqrt(s)=200GeV
Mid rapidity ($|\eta| < 0.35$)

$pp \rightarrow \gamma X$:
PRL 98, 012002



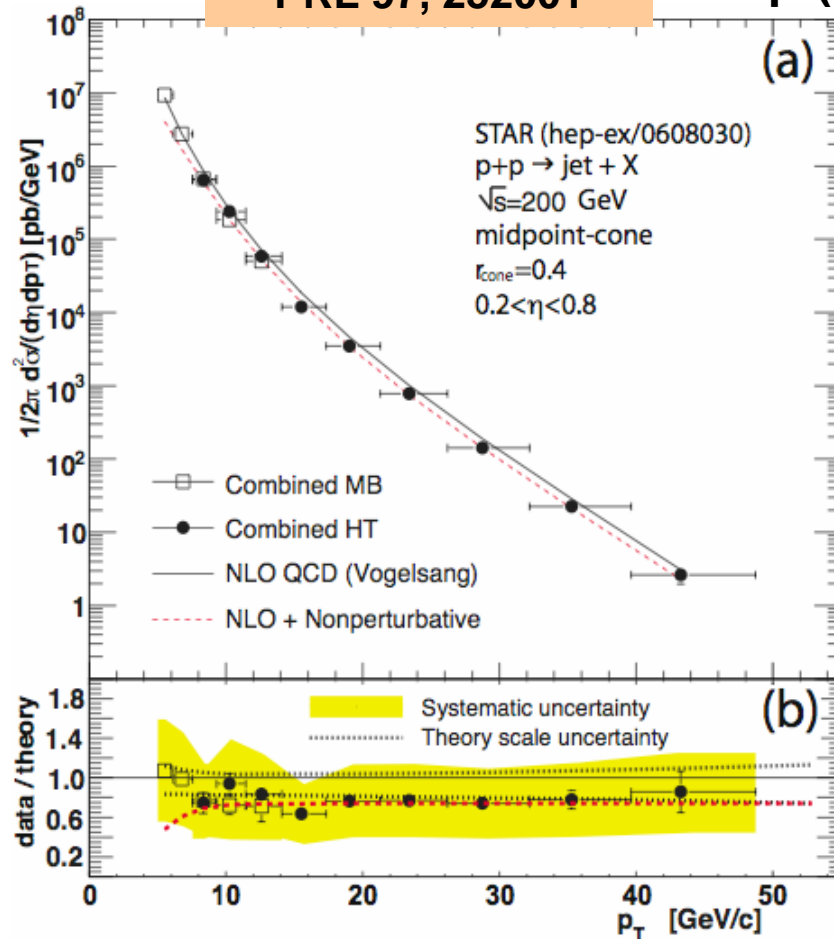
And also eta, h^\pm , single electron (from charm)
 All measurements support the pQCD calculation.

pQCD our theory baseline is OK!

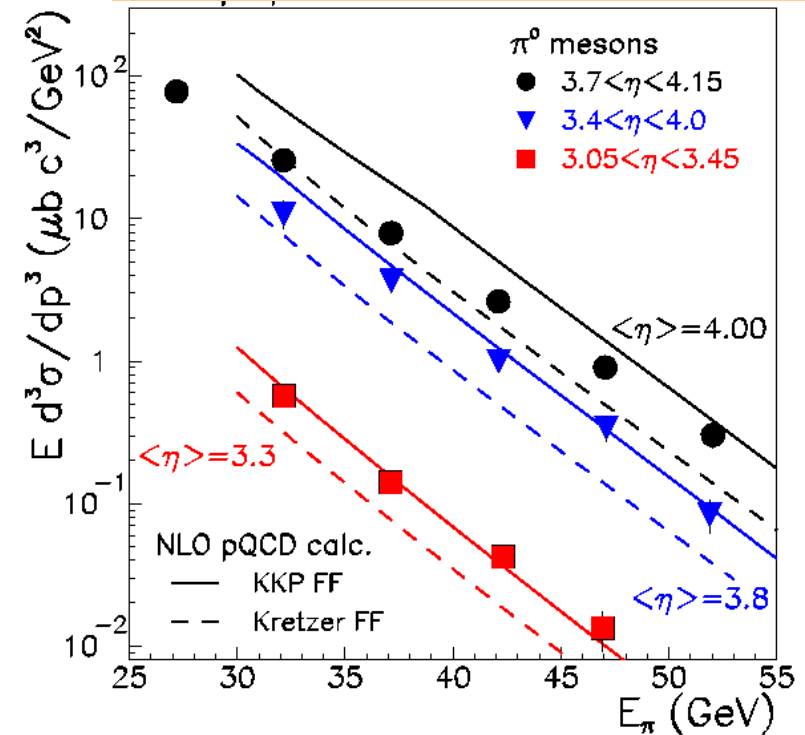
Measurements from STAR

STAR: $pp \rightarrow \text{jet } X$
PRL 97, 252001

$\sqrt{s}=200\text{GeV}$

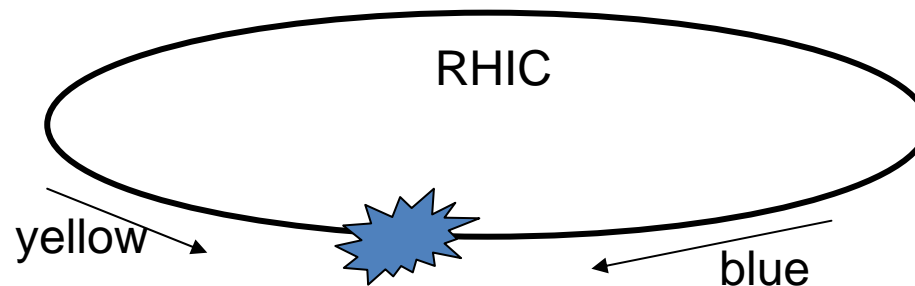


STAR: π^0 forward rapidity
PRL 97, 152302



It works even for the forward π^0 production.

Asymmetry measurement



120 bunches (revolution time = 1.2 [μ s])

Yellow + - + - + -
Blue + + - - + +

$$A_{LL} = \frac{1}{P^2} \cdot \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

$$R \equiv \frac{L_{++}}{L_{+-}}$$

Relative luminosity
determined by BBC,ZDC counts

Check relative luminosity measurement

Using the same hard scattering as the luminosity measurement

⇒ Need to check if there is no A_{LL} in BBC

⇒ Comparison between BBC and ZDC

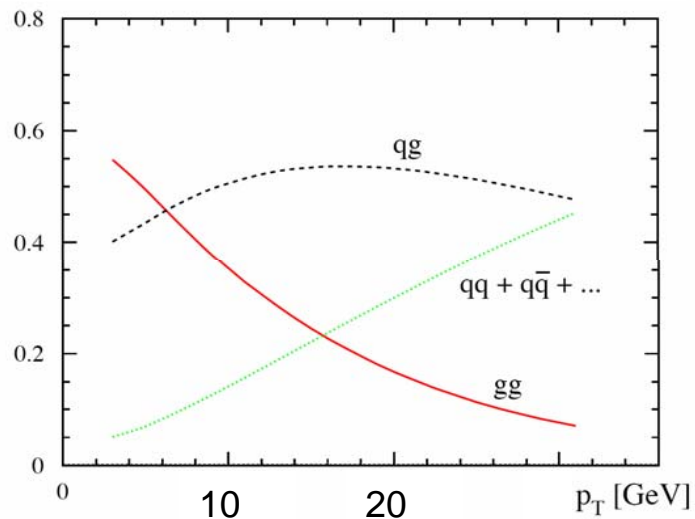
Check bunch related systematic uncertainty

Enough statistics in a bunch ⇒ check rate per bunch

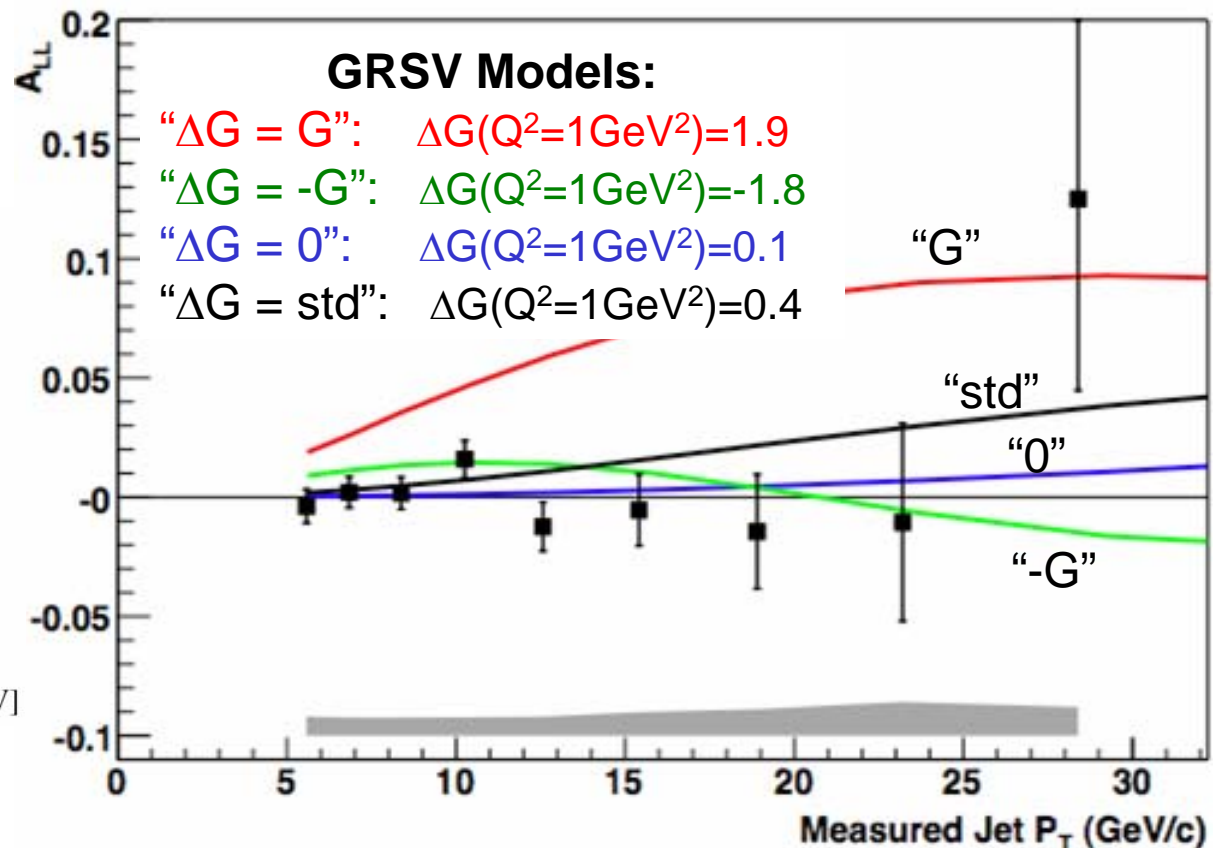
If it's not enough ⇒ assign random spin pattern ⇒ confirm null asymmetry

Which channel to begin with?

STAR : Jet production
high energy jet patch trigger
Jet reconstruction
No fragmentation process



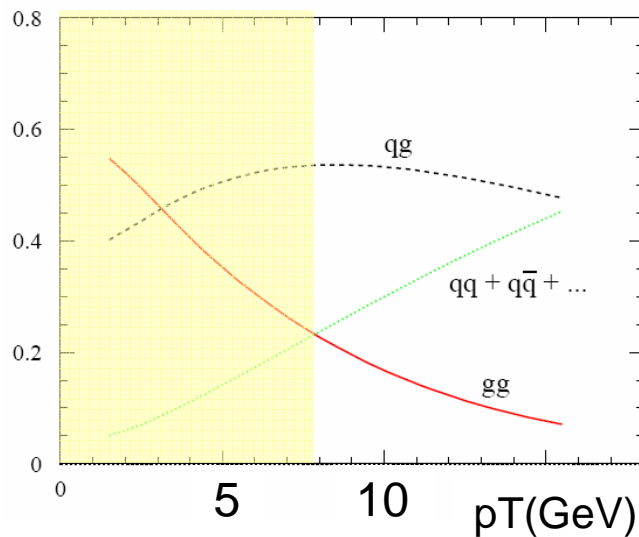
STAR Preliminary Run5 ($\sqrt{s}=200$ GeV)



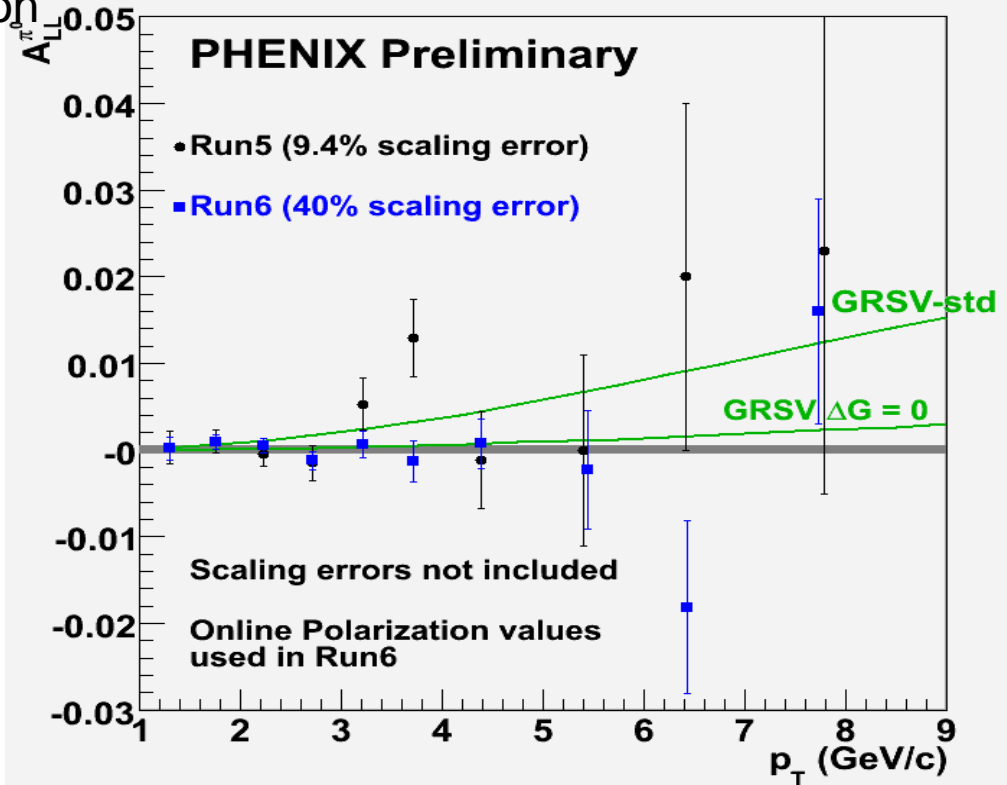
Run3: PRL 97,252001 (2006)

Which channel to begin with?

PHENIX : π^0 production
EMCal trigger favored
gluon dominates in low-mid p_T region



PHENIX Preliminary Run6 ($\sqrt{s}=200$ GeV)

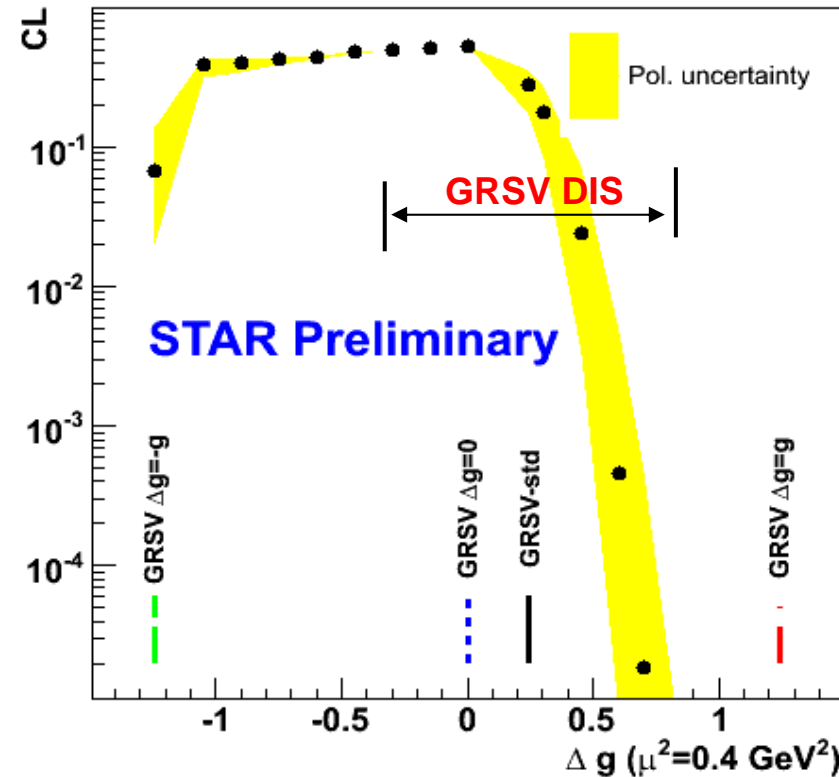
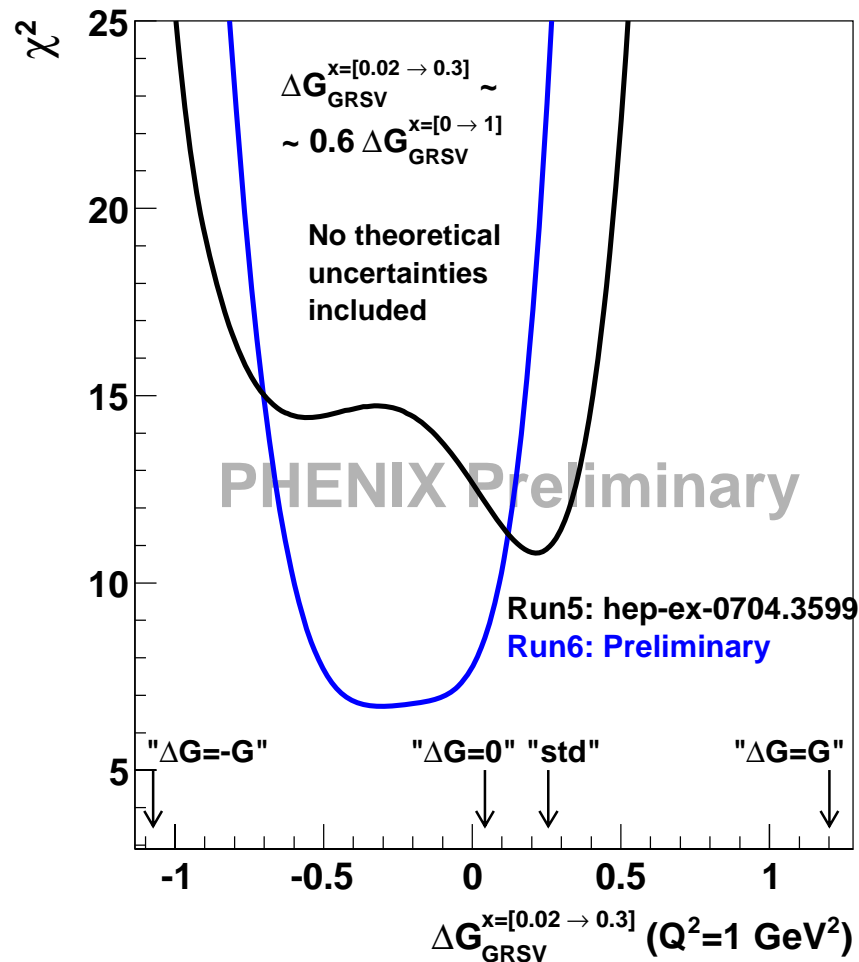


Run3,4,5: PRL 93, 202002; PRD 73,
091102;

hep-ex-0704.3599

Comparison to the GRSV model

Calc. by W.Vogelsang and M.Stratmann



"max ($\Delta G = G$)" scenario is rejected.

It is a start point of feedback to theory calculations.

Other models with different assumption
Universality to results from polarized DIS

Interim Summary

Now we know,

- In $p+p$ ($\sqrt{s}=200\text{GeV}$), the factorized pQCD works.
 ΔG is not large.

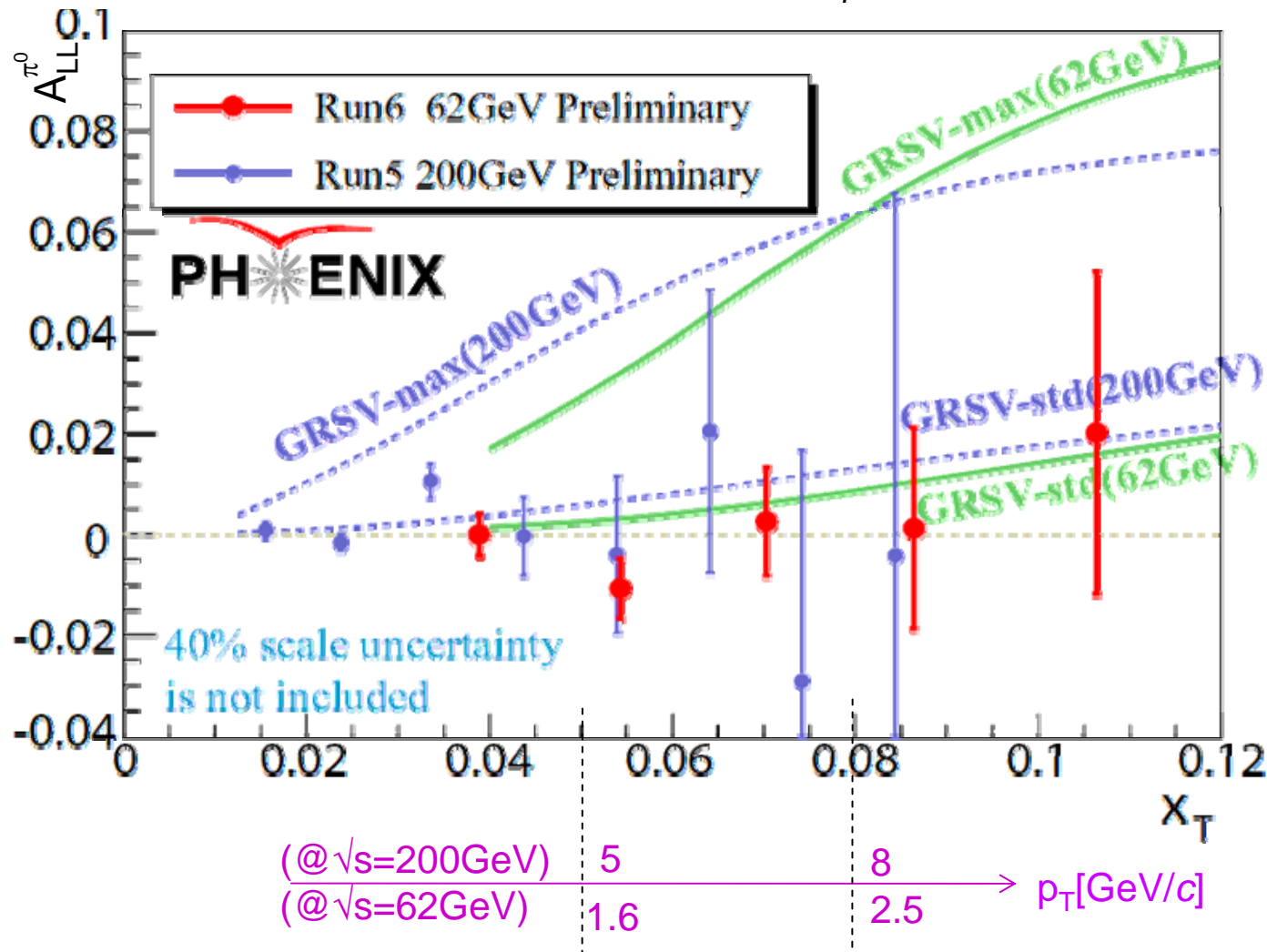
What is the next?

- With high integrated luminosity ($10\text{pb}^{-1} \rightarrow 100\text{pb}^{-1}$ or more)
Higher statistics (π^0 , Jet)
Various channels (e.g. direct γ , charm...)
- x_{gluon} dependence
Full reconstruction of collision kinematics
Different collision energy (\sqrt{s}) \searrow 62.4GeV, \nearrow 500GeV
- Beyond the ΔG measurement
Quark flavor decomposition
Other ideas

Lower the collision energy?

Lower collision energy ($\sqrt{s}=62\text{GeV}$)
 $\times 0.1$ instantaneous luminosity,
 $\times 100$ production for the same x_T

Run6 62.4GeV $\sim 0.06 \text{ pb}^{-1}$
 Run5 200GeV 1.8 pb^{-1}

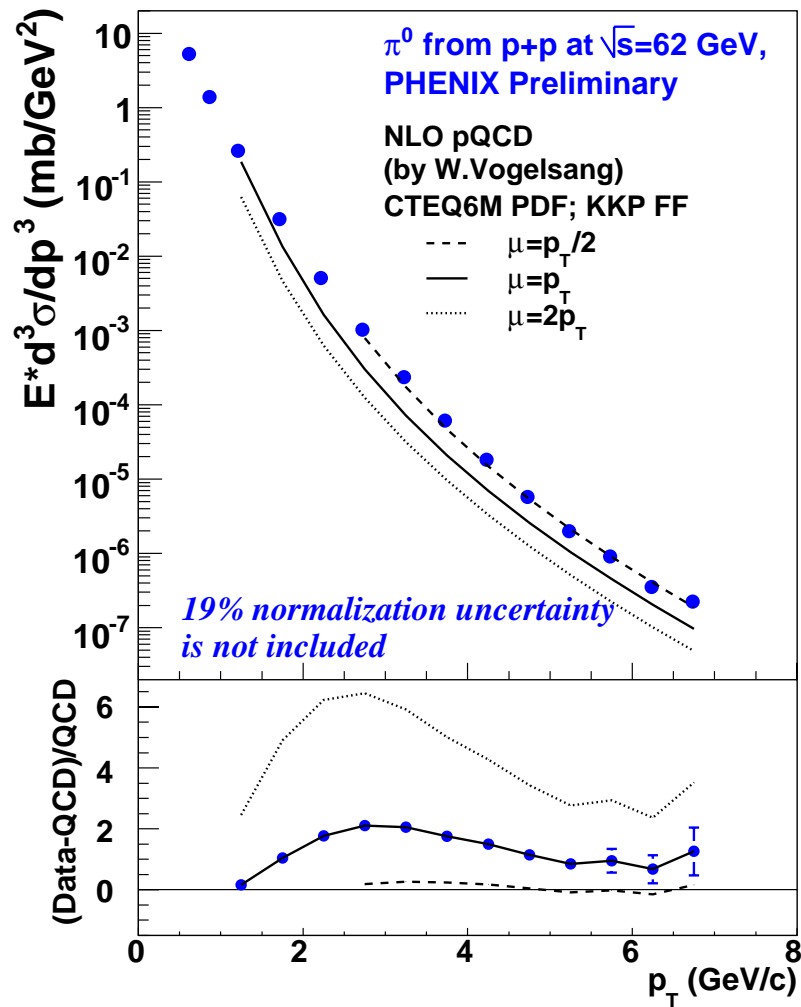


The calculation almost
 scales to x_T .
 So low \sqrt{s} is effective.

An issue in the low energy collision

Is pQCD applicable?

Is the theory scale uncertainty large?



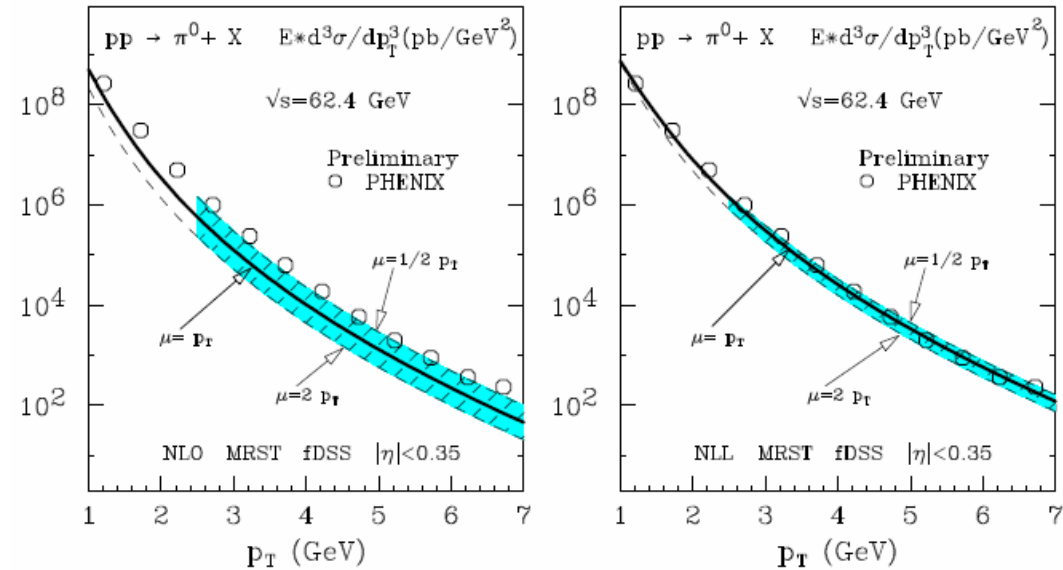
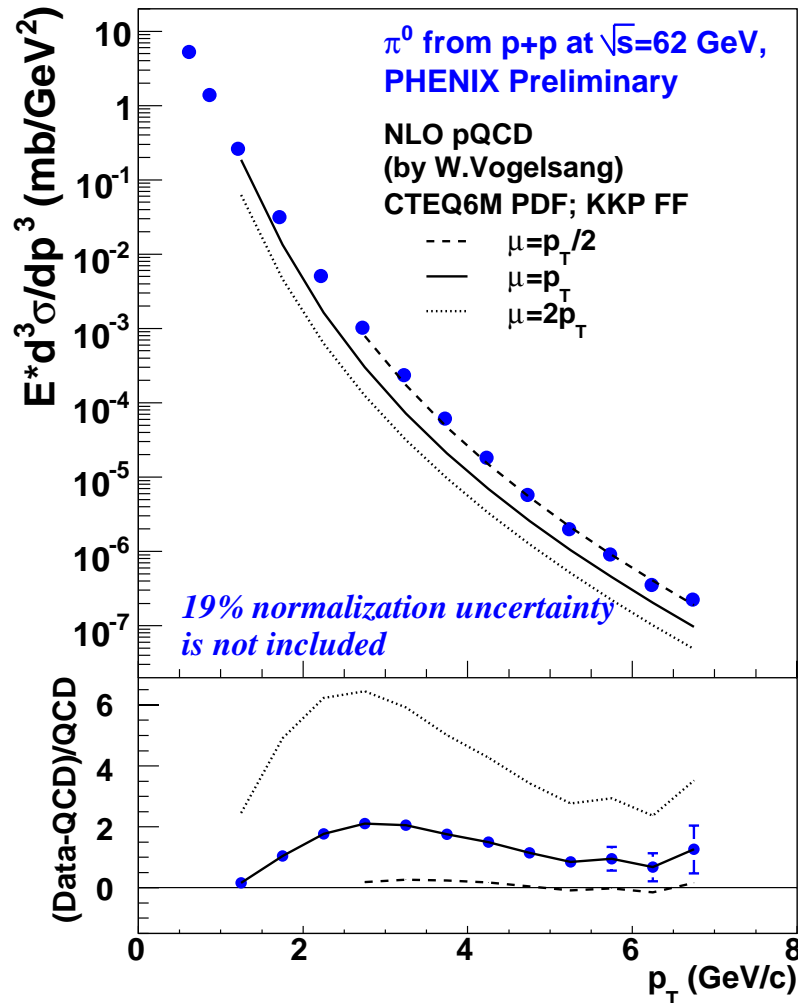
An issue in the low energy collision

Is pQCD applicable?

Is the theory scale uncertainty large?

New !

arXiv:0708.3060 (Aug.2007)



The progress in theory side may guarantee this measurement.

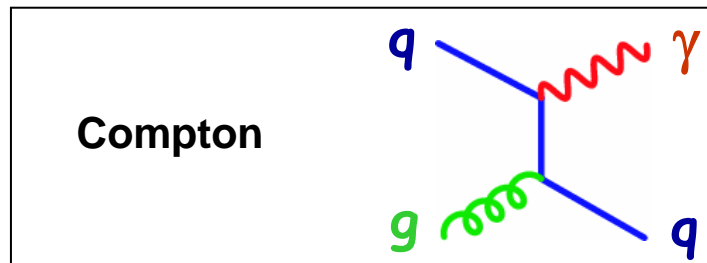
I think this is one of the options in the future.

● Is direct γ the golden probe?

- In the theory side..... yes

~80% from the gluon Compton process

No or small problem of the fragmentation function



- In the experimental side..... not really true

It is rare compared to hadronic production

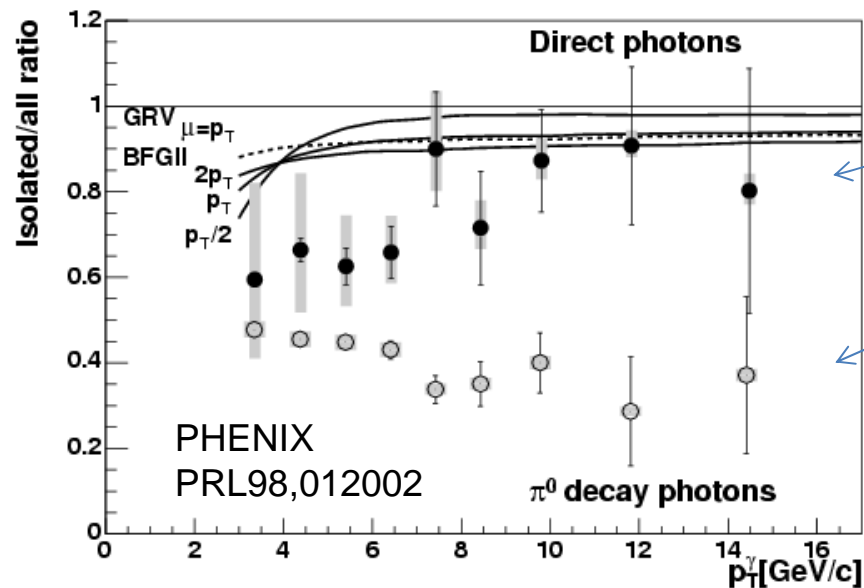
Photon contamination from hadronic (π^0) decays.

Issues in direct γ asymmetry measurement

- It is a rare process,
but the good thing is they can be triggered by the EMCal.

- Hadronic decay contamination

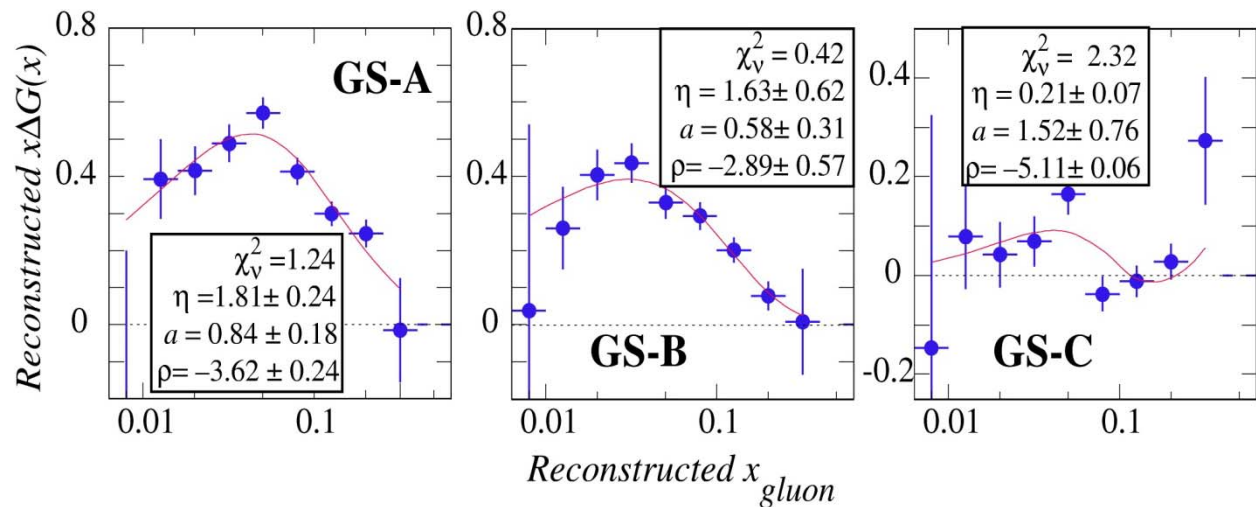
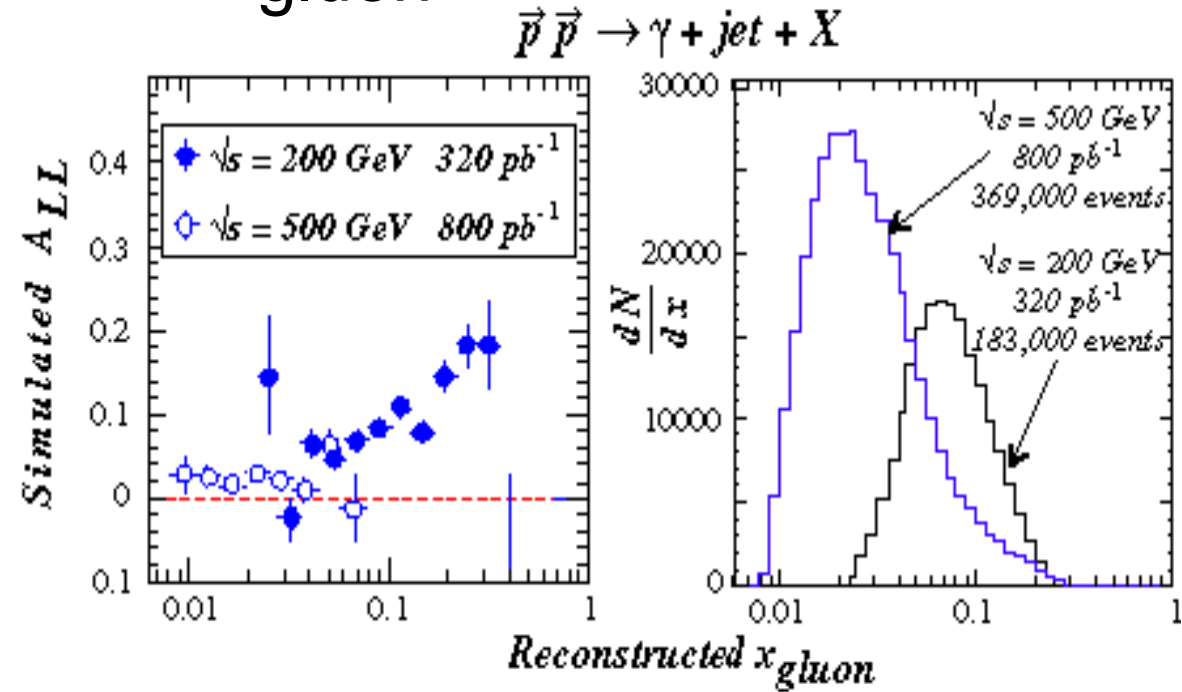
An isolation cut reduces the hadronic decay photons.



A bias caused by the cut?
Remaining background effect?

Mapping the x_{gluon} dependence

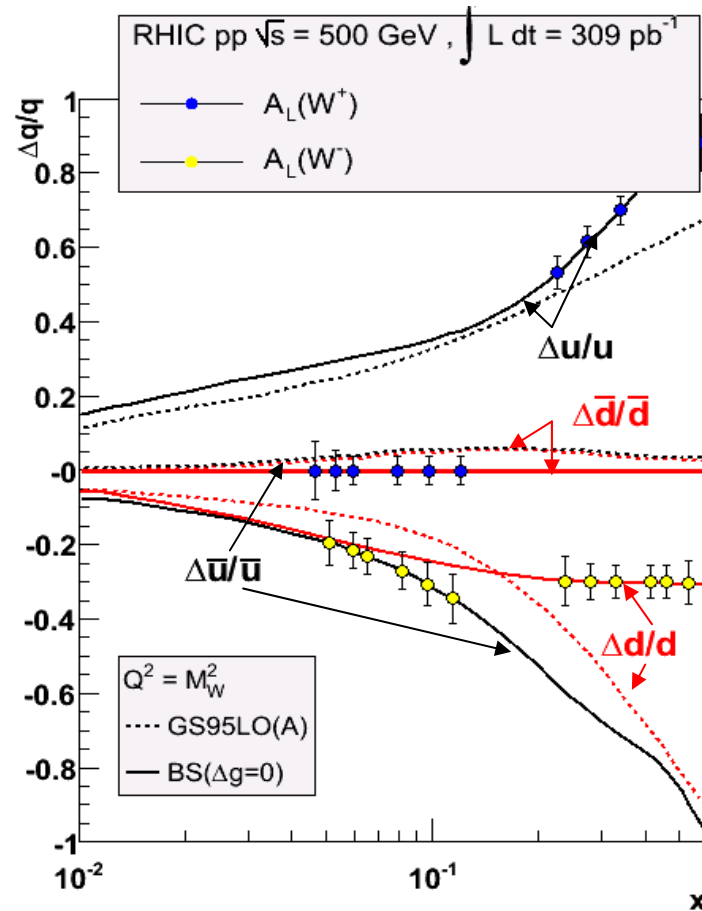
- Kinematical reconstruction by tagging γ +jet, 2jets
- STAR has an advantage with its large acceptance.



GS-A,B,C models of $x\Delta G(x)$ from Gehrmann and Stirling, PR **D53**, 6100 (1996).

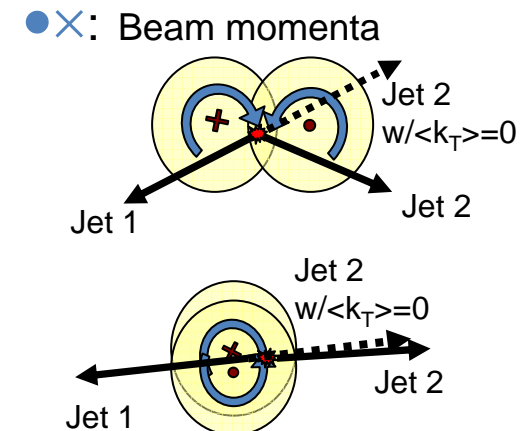
Beyond the ΔG measurement

- Proton-spin quark flavor decomposition with parity violating process



- Spin transfer analysis with self-analyzing decay channel (Λ)
Access to strange quark components?

- Jet kT asymmetry (a probe of quark orbital angular momentum?)





Prospects

From research plan BNL-73798 (Feb.2005)

Table 6: *RHIC spin example schedule, 10 physics weeks per year, technically driven. Luminosities are 0.7 times maximum.*

Fiscal year	Spin Weeks	CME(GeV)	P	L(pb ⁻¹)	Remarks
2002	5	200	0.15	0.5	First pol. pp collisions! Transverse spin
2003	4	200	0.3	1.6	Spin rotators commissioned, first helicity measurements
2004	3	200	0.4	3	New betatron tune developed, first jet absolute meas. P
2005	10	200	0.5	14	$A_{LL}(\pi^0, \text{jet})$, also 500 GeV studies
2006	10	200	0.7	32	AGS Cold Snake commissioned, NEG vacuum coating complete
2008 2007	10	200	0.7	88	
2008	10	200	0.7	106	Direct γ
2009	5	200	0.7	35	target complete for 200 GeV;
	5	500	0.7	180	PHENIX μ trig.; W starts
2010	10	500	0.7	266	STAR forward tracker; W physics
2011	10	500	0.7	266	
2012	10	500	0.7	266	Completes 500 GeV target

2008 Run is a important step !

Summary

- RHIC provides an unique opportunity to study the proton spin structure. After 5 years of running, our measurements conclude ΔG isn't very large.
- The RHIC performance (both luminosity and polarization) is improving. In the next years, the accuracy of the current measurements improves. And measurement of other rare processes and a kinematical slices will be available.
- As the theory baseline application expands, it is interesting to scan other collision energies to access other kinematical regions.
- The quark flavor decomposition using the parity violating process is one of big upgrade projects in both PHENIX and STAR experiments.